Silvical Characteristics of Green Ash

(Fraxinus pennsylvanica)

by Jonathan W. Wright

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Preface

MUCH of the silvical information on our forest trees is widely scattered and sometimes difficult to find. To make this material more readily available, the Forest Service is assembling information on the silvical characteristics of all the important native forest tree species of the United States. It is expected that this information will be published as a comprehensive silvics manual.

This report presents the silvical characteristics of one species. It contains the essential information that will appear in the general manual but has been written with particular reference to the species in the Northeast. Similar reports on other species are being prepared by this Experiment Station, and by several of the other regional forest experiment stations.

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About the Author ...

JONATHAN W. WRIGHT *took his B.S. degree in forestry at the University of Idaho in 1938. He received M.F., M.A., and Ph.D. degrees at Harvard University, with genetics his major field. From 1942 to 1945 he was an instructor in forestry at Purdue University. He joined the Northeastern Forest Experiment Station the following year as geneticist, headquartered at the Morris Arboretum. A recognized authority on forest genetics, Dr. Wright has published many papers both in this country and abroad. He left the Experiment Station in 1957 to become Associate Professor of Forestry at Michigan State University, East Lansing, Mich.*


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The Green Ash

THE "green" in green ash (*Fraxinus pennsylvanica* Marsh.) refers to the leaves. They are nearly as bright green on the lower surface as on the upper. The specific Latin name *'pennsylvanica'* was given to the species because it occurs in the United States and because in 1785 Pennsylvania and the American colonies were often considered as synonymous in the minds of European botanists.

The taxonomy of the species is somewhat confused. Several authoritative treatises *(10, 27, 29)* and most state floras recognize two varieties: green ash (*F. pennsylvanica* var. *lanceolata* (Borkh.) Sarg.), and red ash (*F. p.* var. *pennsylvanica*). Also, Miller *(23)* has considered western Oregon ash (*F. latifolia* Benth.) and velvet ash (*F. velutina* Torr.) to be subspecies of the eastern American green ash. Little *(19)*, however, treats Oregon ash and velvet ash as separate species, and does not recognize varieties of green ash. Little's concepts are accepted in this paper.

Green ash and white ash (*F. americana* L.) are sometimes confused in the field. This is understandable if the identifications are based on shaded leaves. However, there is no reason for mistaken identity if sun leaves or fruit are available. In green ash the leaves are green on both surfaces and sharply serrate, and the samara wing is decurrent halfway down the slender seed; in white ash the leaves are white on the lower surface and dentate, and the samara wing is terminal on the cigar-shaped seed. The Carolina ash (*F. caroliniana* Walt.) is scarcely separable from green ash on vegetative characters but is distinguishable by its flat, wide fruit.

Green ash is the most widely distributed--but not the most common--of all the American ashes (fig. 1). Its natural range extends from southern Nova Scotia to southern Saskatchewan and Montana, and southward to Texas and northern Florida. In the western part of its range it is the only representative of the genus. Green ash has been commonly planted in England *(9)*; there it grows to heights of 60 feet. It is also doing well in the Arboretum des Barres at Nancy, France *(28)*.

Habitat Conditions

CLIMATE

The climate within the natural distribution area of green ash is sub-humid to humid. Over this area there is a range in annual precipitation of 15 to 60 inches, in warm season precipitation of 10 to 35 inches, in average January temperature of 0 to 55° F., in average July temperature of 65° to 80° F., in average snowfall of 0 to 100 inches, and in average length of the frost-free season of 120 to 280 days *(35)*.

Geographic-origin tests conducted in Minnesota and Massachusetts point to moisture and winter temperature as the most important factors governing the distribution of the geographic ecotypes and presumably the species as a whole. In Meuli and Shirley's studies of drought resistance, trees from the Central Plains States suffered much more drought injury than did trees from the northwestern part of the species' range *(22)*. Wright's provenance tests showed pronounced ecotypic differences in susceptibility to the low winter temperatures found in central Massachusetts *(39)*. Trees from the southern part of the range grew vigorously during the summer but each winter killed back nearly to the ground. The northern trees were slower growing but hardy.

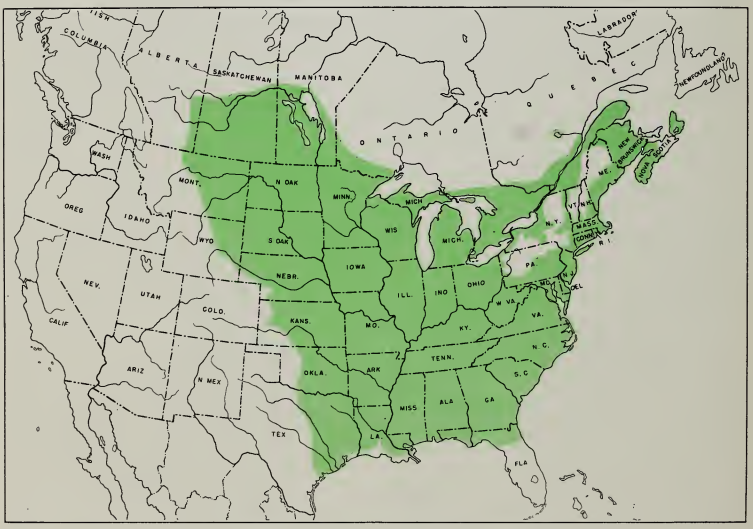

Figure 1.--*The natural range of green ash.*

TOPOGRAPHY AND SOILS

Green ash is found most commonly on alluvial soils along rivers and brooks, and less frequently in swamps *(4, 15, 17)*. It lines the watercourses in the western parts of its range where rainfall is insufficient to support upland tree growth. It is common on land that is subject to flooding once or twice a year, and remains healthy when flooded up to 40 percent of the time during the growing season *(11)*. Unlike the black ash (*F. nigra* Marsh.), it is not usually found in peat bogs. There is a published report of its having invaded moist upland soils in Nebraska *(34)*, but elsewhere in its range it is rare in the natural upland forest.

In spite of the fact that natural stands are almost completely confined to bottomlands, this species grows well when planted on moist upland soils. It has been one of the most successful and commonly planted hardwoods in the Great Plains shelterbelts *(16, 24, 38)*. From North Dakota to Texas it has thrived when planted on medium- to coarse-textured upland sands and loams with good moisture relations and with neutral to alkaline reactions. In a few such places where the water table is only 4 to 8 feet below the surface it is reproducing naturally. One successful planting in the Northeast was established on a fertile upland soil that originally had supported a northern hardwood forest.[1] And most of the English and French plantings are on moist upland soils *(9, 28)*.

The natural distribution pattern of the species is such as to indicate that it needs high soil moisture. This is substantiated by studies in Illinois prairie-soil plantings *(30)*. In these, the soil under successful green ash was found to be constantly moist. It is also borne out by the fact that in the Great Plains the best shelterbelt plantings are on coarse-textured soils. In regions of deficient rainfall more water is available for tree growth on such sites than in heavy clay soils.

In Iowa fertilizer experiments, green ash was more tolerant of high soil alkalinity than were several other hardwood species; however, it showed severe chlorosis when grown on a soil with a pH of 8.1 *(21)*. In these tests it grew better on forest soils than on prairie soils, presumably because suitable mycorrhizae and organic matter were present in the forest soil. It responded to the addition of 2,000 pounds of nitrogen but not to added phosphorous or potassium. However, the response was not great enough to indicate that the addition of fertilizer to the average Iowa field was economically justified for green ash.

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[1] Unpublished data, Northeastern Forest Experiment Station.

A later Iowa study of 30 different plantations, most of them about 20 years old, has further emphasized the importance of soil characteristics on the growth of green ash *(12)*. This study was limited to the Lindley-Weller soil association area of southeastern Iowa. History prior to plantation establishment, amount of erosion of the A horizon, and percent foliar nitrogen were the principal factors associated with success of the plantations.

In this Iowa study, growth was much better on areas that had not been cultivated previously (2.37 feet per year height growth) than on areas that had previously been intensively pastured (1.76 feet per year) or cultivated without maintenance of soil fertility (0.92 feet per year). Growth was better if there had been no previous erosion of the A horizon (1.99 feet per year) than if up to 50 percent of the A horizon had been removed (1.60 feet per year) or if up to 100 percent of the A horizon had been removed (0.81 feet per year). Plantings with 2.25 percent nitrogen in their leaflets averaged 2.40 feet per year in height growth whereas those with 1.50 percent nitrogen in their leaflets averaged only 0.81 feet per year height growth. Less than 10 percent of the green ash plantings examined were regarded as satisfactory, apparently because of unsuitable soil conditions. In contrast, nearly all the pine plantations on similar sites were growing well.

Despite its rather exacting soil requirements, green ash has been used with considerable success in attempts to afforest spoil banks resulting from strip-mine operations in Pennsylvania, West Virginia, and the Central States *(6, 18)*. Survival in these plantings usually has been high. Growth rates up to 1 foot per year have been reported. Although these growth rates are much lower than on fertile alluvial soils, they are high enough to make green ash one of the favored species for strip-mine afforestation (fig. 2).

BIOTIC

Associated Species

Green ash is most common in the silver maple-American elm, pin oak-sweetgum, sweetgum--yellow-poplar, sweetgum-Nuttall oak-willow oak, sugarberry-American elm-green ash, and overcup oak-water hickory cover types as recognized by the Society of American Foresters *(32)*.

It is a minor component of the bur oak and white oak-red oak-hickory cover types, and is an understory species in the cottonwood, black willow, and loblolly pine-hardwood cover types and in the most fertile portions of the aspen cover type *(17)*.

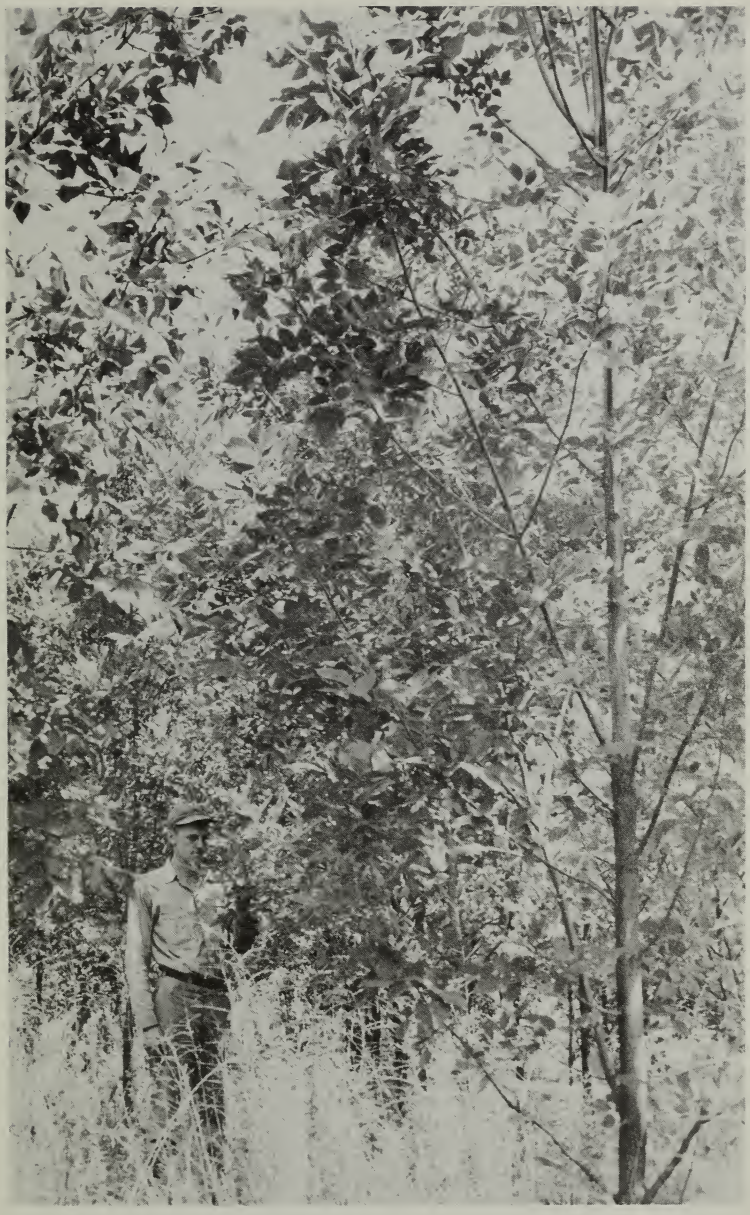

Figure 2.--*Green ash is one of the species favored for planting on strip-mine spoil banks. This plantation is on fertile spoils in Fulton County, Ohio.*

Its most common associated species are boxelder (*Acer negundo* L.), red maple (*A. rubrum* L.), pecan (*Carya illinoensis* (Wangenh.) K. Koch), sugarberry (*Celtis laevigata* Willd.), sweetgum (*Liquidambar styraciflua* L.), American sycamore (*Platanus occidentalis* L.), eastern cottonwood (*Populus deltoides* Bartr.), plains cottonwood (*P. sargentii* Dode), quaking aspen (*P. tremuloides* Michx.), black willow (*Salix nigra* Marsh.), willow oak (*Quercus phellos* L.), and American elm (*Ulmus americana* L.)

Figure 3.--*A severe infestation of oystershell scale on green ash. This is one of several pests that attack the species.*

Insect & Disease Pests

Many insects feed occasionally on green ash *(8, 25)*. One of the most serious is the oystershell scale (*Lepidosaphes ulmi* (L.)), which is distributed throughout the Northeast and can cause considerable mortality among seedlings and small trees (fig. 3). During the summer of 1958 this scale was especially troublesome on spoil bank plantings in Pennsylvania. The carpenter worm *(Prionoxystus robiniae* (Peck)) bores into the heartwood of large limbs and trunks, permitting the entrance of fungi. The brown-headed ash sawfly (*Tomostethus multicinctus* Roh.) and the black-headed ash sawfly (*Tethida cordigera* (Beauv.)) occasionally

cause serious defoliation of shade trees. Unspecified borers are common in trees planted in the shelterbelts of the Great Plains *(24)*.

There are several diseases that in general are of minor importance.[2] The fungus *Mycosphaerella fraxinicola* (Schw.) House causes a leafspot that sometimes results in premature defoliation of young trees. Anthracnose (*Gloeosporium aridum* (Ell. & Tr.) Arth.) also causes premature defoliation; it is most serious in wet years. A rust caused by *Puccinia peridermiopora* (Ell. & Tr.) Arth. causes distortion of petioles and small twigs. The white mottled heartwood rot (*Fomes fraxinophilus* (Pk.) Sacc.) gains entrance through wounds or broken branches and is most troublesome in the Midwest. In Texas and Oklahoma green ash showed intermediate susceptibility to a root rot caused by *Phymatotrichum omnivorum* (Shear) Duggar *(38)*. The root rot damage is negligible on light soils but is a serious factor militating against the planting of the species on heavy soils. In most nurseries damping-off losses are small.

Animal Pests

The cottontail rabbit, snowshoe hare, white-tailed deer, and three species of birds have been reported as feeding on green ash *(37)*. In reports of natural stands there is usually no mention of serious damage by animals. However, rabbits and cattle may injure unfenced shelterbelt plantings *(1, 24)*.

Life History

FLOWERING AND FRUITING

Green ash is dioecious, that is some trees are male, some female. Flowers are borne over the entire outer portion of the live crown *(42)*. Flowering has been observed on a 7-year-old tree that was only 12 feet tall. Usually, however, flowering does not start until trees are 3 to 4 inches in diameter and 20 feet tall. A high percentage of favorably situated male and female trees of flowering size flower annually and many female trees fruit annually. The percentage of the total trees that flower and fruit regularly is higher than in white ash.

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[2]Alma M. Waterman, personal communication.

The flowers of green ash appear before the leaf buds start to enlarge--in March or April in Florida *(5)*, and late April or early May in Pennsylvania *(42)*. Male flower buds require 1 to 2 weeks to pass from the unenlarged winter condition to completion of pollen-shedding. Within a stand, the range among individual trees in onset of pollen-shedding is 2 to 3 days. Each individual tree sheds pollen over an interval of 3 to 4 days. The pollen, which is wind disseminated, travels relatively short distances, most of it falling within 200 or 300 feet of the source *(40)*.

Flower-bud enlargement starts a few days later on female trees than on males. The stigmas of the female flowers are receptive as soon as they emerge from the bud, and they remain receptive for about a week *(41)*. Receptivity appears to end just before the stigmas start to wither. The female flowers and young fruit are very sensitive to late spring frosts.

The technique of controlled pollination in green ash is relatively simple *(41)*. By bagging the female flowers before they open, then injecting pollen from the selected source into the bag after the flowers open, sets of 25 to 50 sound seeds per panicle often can be obtained.

Within a month after pollination the samaras developing from fertilized flowers reach mature size *(41)*. There seems to be no parthenocarpy (production of fruit without pollination); unpollinated flowers or flowers pollinated by an unrelated ash species drop off within the first month. The growth and ripening of embryos lag behind the growth of the samaras, and are not completed until late September or early October. Seed ripeness can be determined easily in the fall by macroscopic examination of excised embryos. When ripe the embryo should be about 1 centimeter long, slightly less than 1 millimeter in diameter, white, and more firm than a crisp carrot.

The seeds start to fall as soon as they ripen and continue to fall until late winter or early spring. Most of the seed is wind-dispersed within a few hundred feet of the parent trees. There is also some dispersal by water, but the importance of water as a long-distance dispersal agent is not known *(36)*.

VEGETATIVE PROPAGATION

Green ash of sapling or pole size sprouts readily. The resultant sprout clumps usually contain only one or two stems.

Cuttings made from young trees root rather easily under good greenhouse rooting conditions *(14)*. However, no practical way to root cuttings from older trees has yet been developed. Green ash can be bench-grafted or field-grafted successfully by the usual methods.[1] Fortunately for the potential grafter, a 5-year supply of understocks can be "stored" by severely root-pruning young seedlings and heeling them in by groups of 50 or 100. Most of the seedlings will remain alive under such conditions but will grow so little that they will supply an assortment of small understocks whenever needed. Green ash understocks have been used successfully with scions of several other ash species.

For experimental purposes limited quantities of clonal material can be obtained easily by severely pruning the tops and roots of 2-year-old seedlings, splitting the rooted stumps longitudinally, waxing the open surfaces, and replanting the split portions in a shaded and well-watered nursery.[1] In preliminary tests survivals of over 50 percent were obtained even without the precaution of waxing and shading the split portions.

SEED HANDLING

Seed is most easily collected from standing trees in early October. Large quantities of seed can sometimes be swept up from roads in late October or early November.

Green ash seed may be sown soon after collection, or it may be stored for a year at room temperature without serious loss of viability. However, the germination percentage probably decreases somewhat during such storage. The longest successful storage recorded was for 8 years *(3)*. That seed was kept at a temperature of 41° F. and at a moisture content of 7 to 10 percent.

Freshly collected green ash seed is dormant because of an impermeable seed coat *(7, 26, 33)*. This dormancy can be overcome by moist stratification for 60 to 90 days at refrigerator temperatures *(36)*. The dormancy of green ash is more easily overcome and the germination percents are usually higher than for other commonly grown ashes.

In nature and in most nurseries the need for stratification is avoided by sowing the seed in the autumn. The best procedure is to place the seed about ½ inch deep in a fertile mineral soil and to mulch it over winter. Of course, in nature most seeds do not reach the optimum depth, and seed mortality is exceedingly high.

SEEDLING DEVELOPMENT AND EARLY GROWTH

In the latitude of Pennsylvania, fall-sown seeds germinate in early May. The seedlings are epigeal; that is, after germination the cotyledons are above ground. Germination often will be hastened by shading the seedbeds to conserve moisture in the upper soil layers. However, with adequate moisture the seedlings grow best in full sunlight; therefore, removal of the shades 2 to 3 weeks after germination usually is advisable if the beds can be watered. Damping-off losses usually are slight.

Under good (not necessarily optimum) nursery conditions, seedlings grow about 1 foot tall the first year and another 1½ feet the second season. For such growth they probably need a growing space of about ¼ square foot the first year and 1 square foot the second year. However, they can survive at least 2 or 3 years under more intense weed competition or overcrowding than other common bottomland hardwoods such as eastern cottonwood and American elm, whether in the nursery or in the wild. Under these less-than-optimum conditions the seedlings may grow only 2 or 3 inches per year.

In central Massachusetts provenance tests, no differences were noted in the date at which green ash seedlings started growth in the spring *(39)*. On the other hand, there were genetic differences in the date of cessation of growth. Trees of northern origins completed height growth and set terminal buds by late June, and shed their leaves in late September before the first frost. This stock was winter-hardy. In contrast, trees of southern origins exhibited an indeterminate growth habit and retained live green leaves after the first severe frost. Seedlings of the most southern origins died back nearly to the ground the first winter.

Green ash nursery stock can stand severe mishandling during the dormant season without dying. Even after exposure of the roots to open air for several minutes, or after pruning the roots to within an inch of the root collar, seedlings can be forced into making 6 or 8 inches of growth the first season. As mentioned before, seedlings will remain alive 4 or 5 years after being heeled-in in large bundles. Untransplanted seedlings that have suffered from crowding or shading exhibit this same ability for prompt recovery after release.

Uninjured nursery seedlings develop no side branches during the first year, no matter how favorable the growth conditions. On vigorous seedlings the uppermost 1 or 2 pairs of lateral buds develop into branches during the

second or third year; weak seedlings may remain free of branches for several years. In both seedling and later stages green ash is branchier than white ash.

Figure 4.--*When a green ash seedling is bent, or planted crooked, a sprout develops from the base to become the new leader.*

If the terminal bud is removed during the growing season from seedlings of southern origin, branches develop on the current year's growth *(39)*. Peculiarly, these branches arise from adventitious buds above the already-formed lateral buds, not from the buds that were present before the injury occurred. The dominance exerted by the apical bud can also be lost if the seedling is bent or planted crooked. In such a case a sprout develops from the base of the tree and takes over as a new vertical leader (fig. 4).

Apical dominance is usually strong enough in vigorous, uninjured, open-grown trees so that they have a single, straight stem until they are 15 or more feet tall. If the apical dominance is lost by the removal of the terminal bud, the uppermost lateral branch quickly takes over and reasserts dominance over the lower branches. In slowly growing, shaded specimens the tendency for quick reassertion of apical dominance following deer nipping or frost injury to the terminal bud is much less pronounced. As a consequence, understory seedlings frequently have poor stem form.

SAPLING STAGE TO MATURITY

In about 1,000 shelterbelts in the Great Plains, green ash averaged 1.3 feet per year height growth for its first 6.5 years *(24)*. Open-grown trees planted on a fertile soil in Philadelphia grew 45 to 55 feet tall and 8 to 12 inches in diameter in 21 years. These growth rates are lower than those reported for white ash. There are few data on the growth rates or volumes of trees grown under stand conditions.

In most areas this species reaches heights of 50 to 60 feet and diameters breast high of 1½ to 2 feet *(29)*. It attains larger average maximum sizes in the bottomlands of the Central States. Dr. C. A. Schenk reported finding a tree 138 feet tall and 5 feet in diameter along the Wabash River in Indiana. The largest living green ash on record is in Big Oak Tree State Park, Missouri. Its height, diameter breast high, and crown spread are respectively 106 feet, 4.4 feet, and 79 feet *(2)*.

Sapling and mature green ash trees are usually branchier and more crooked than are white ash trees grown at similar spacings.

The root systems of green ash and 30 other shelterbelt species in a snow-trap planting in North Dakota were studied by Yeager *(44)*. The soil was a Fargo clay, with a 3-foot layer of black surface soil overlaying a light-colored, calcareous, clayey soil with no hardpan. The soil was poorly drained and was wet in early spring; later in the season the water table was at a depth of 15 feet or more. Of all species studied, green ash had the fourth most extensive root system. The roots of trees 38 feet tall had penetrated 48 feet laterally and 3.6 feet downward; they were about equally distributed among the upper 3 feet of soil.

Excavations of green ash root systems in nearby areas showed vertical root penetration of 3.2 feet in unirrigated sandy and clay soils and of 4.5 feet along the edges of

sloughs. The extensive root systems undoubtedly contribute to a high degree of wind-firmness in green ash. According to Hopkins' report on wind damage to trees at Hays, Kansas, green ash was the only species among those commonly planted there that was not seriously damaged in 1951 by summer wind storms *(13)*.

TOLERANCE AND PLACE IN SUCCESSION

Green ash is intolerant to moderately tolerant. It comes in early in succession on alluvial soils, either as a pioneer species or following eastern cottonwood, quaking aspen, or black willow *(31, 32)*. It is less able to maintain its position in the crown canopy than its more rapidly growing associates such as red maple and American elm. For this reason the percentage of ash usually decreases with increasing age in mixed elm-ash-maple stands.

Genetic Variation

Green ash is composed of three or more geographic ecotypes (or possibly portions of clines). The trees belonging to these ecotypes are easily distinguishable when growing under uniform conditions in a nursery but not when growing naturally. For that reason they are not given Latin varietal or subspecific names.

Meuli and Shirley demonstrated the presence of three different ecotypes in the Great Plains *(22)*. The population from the arid, northwestern part of the species' range was more drought-resistant than that from the moister central Great Plains. Meuli and Shirley's ecotypes may or may not be identical with those from eastern United States studied by Wright *(39)*. The latter differed from each other in several characteristics. As compared to the Coastal Plain ecotype (Virginia, North Carolina, and South Carolina) the Northern States ecotype (Maine to Minnesota) grew more slowly, had greener petioles, was more winter hardy, and the leaves were less subject to damage by fall frosts. A single progeny from New York was intermediate between the above northern and southern ecotypes in the characteristics named. All trees examined were diploid, with 2n = 46 chromosomes.

The presence or absence of soil or altitudinal ecotypes in the species has not yet been demonstrated. However, there are a few data on individual tree variation. In

one small test clonal differences in hardiness of the leaves to growing season frosts were demonstrated among the open-pollinated offspring of a single female parent. Randomly distributed variation in pubescence and samara shape is presumed to be under genetic control.

Taxonomic analyses indicate that all the genetic variation described up to this point arose within the species rather than as the result of introgression. The green ash is just as distinct from other sympatric species at the northern as at the southern part of its range.

Attempts have been made to cross green ash artificially with three other species--white ash, velvet ash, and European ash (*F. excelsior* L.) *(41)*. The cross green X velvet ash was consistently successful, gave high seed sets, and yielded identifiable hybrids that grew about as fast as the eastern parent. The other two combinations yielded no identifiable hybrids.

Berlandier ash (*F. berlandieriana* A. D.C. of Little *(19)* = *F. pennsylvanica* spp. *pennsylvanica* of Miller *(23)*) of Texas and northern Mexico is a closely related species that probably intergrades with green ash in Texas. There has been no detailed analysis of the border zone between the two species.

The pumpkin ash (*F. tomentosa* Michx.) is a rare hexaploid (2n=138 chromosomes) species of the Coastal Plain and the Mississippi Valley *(43)*. Its leaves, twigs, flowers, and fruit are larger than those of green or white ash but qualitatively similar to one or the other of those two species. Annotations on old herbarium specimens in the major herbaria of the eastern United States show that pumpkin ash nearly always occurs near one or both of the other two species; in Tippecanoe County, Indiana, there is a natural stand with all three species present. The patterns of morphological variation and geographical distribution taken together comprise strong evidence for the view that pumpkin ash is a true-breeding polyploid derivative of a cross between a diploid green ash and a tetraploid white ash.

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